
# Coupled
# Data Assimilation & Prediction Systems
# at the GMAO-NASA

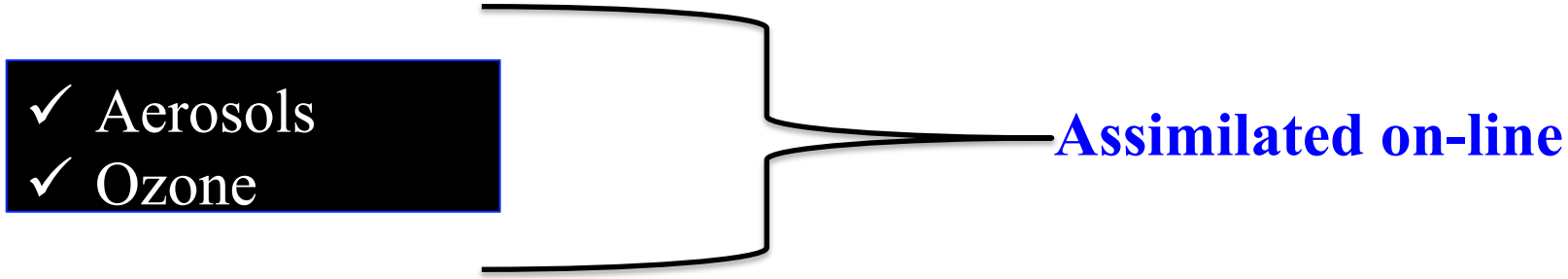
GMAO, NASA-GSFC

(presented by Santha Akella)

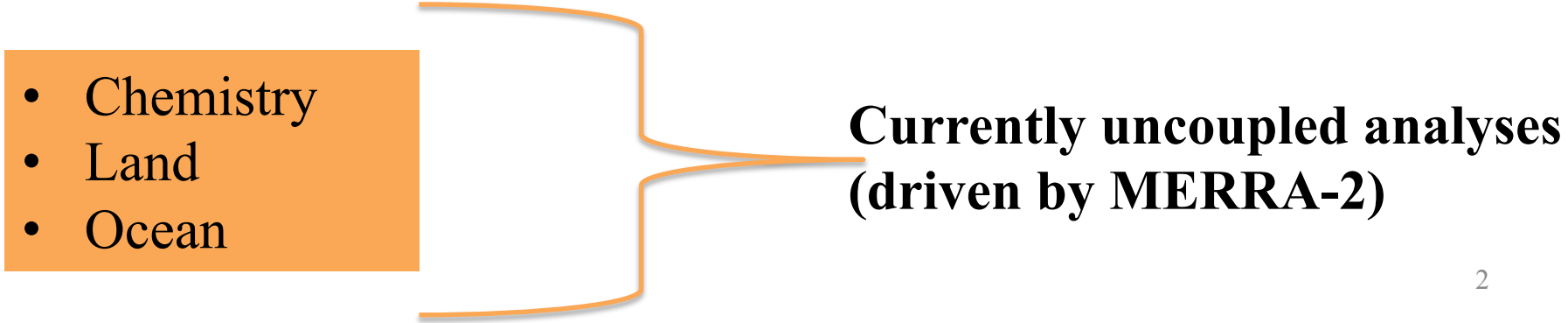
# Outline

- Brief overview of MERRA-2

- Coupled components in MERRA-2




- **Integrated Earth System Analysis (IESA). Full coupling:**



# MERRA-2: System

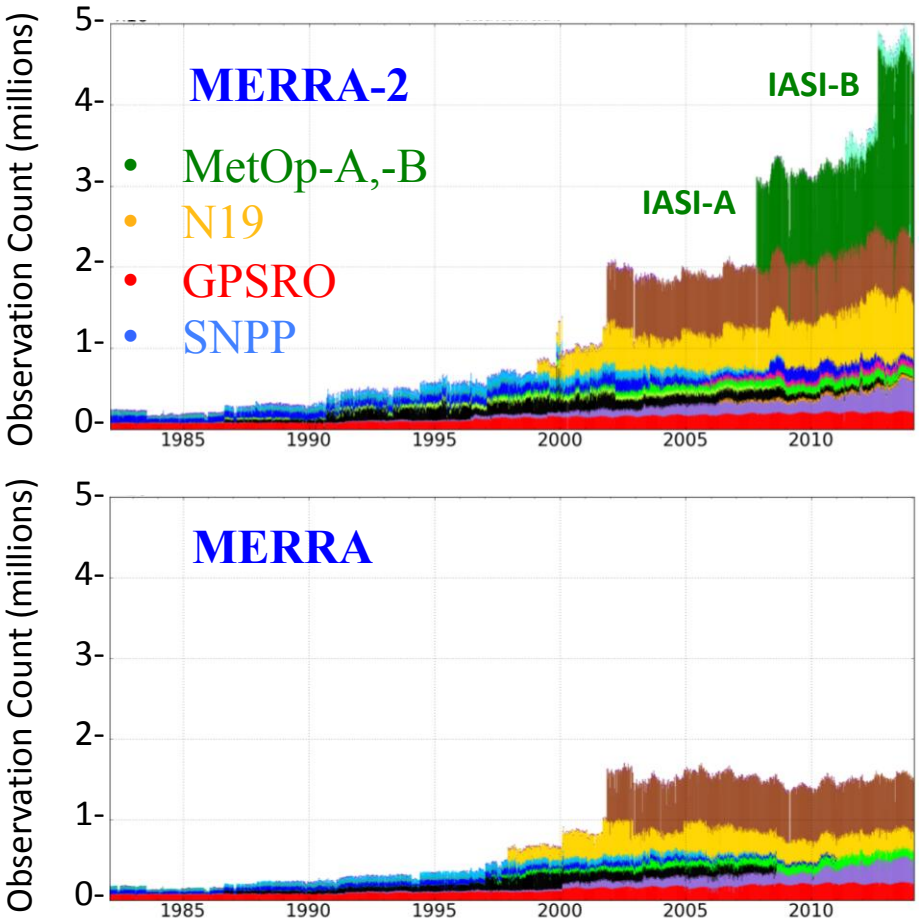
**GEOS-ADAS-5.12.4**: GEOS-AGCM (0.5°x0.625° L72), GSI (3D-Var)

**Key updates** (model, analysis, and observations):

- Cubed-sphere dynamics
- Updated physics: convection, re-evap of rain, snow sublimation
- New moisture control variable
- Bias correction for aircraft temperature observations
- More observations: MetOp-B/SNPP, GPSRO, AuraOMI/MLS
- **Constraints on dry mass** and **globally integrated water** for improved hydrology
- **Aerosol assimilation**, radiatively coupled to AGCM (direct effects)
- **Observation-corrected precipitation** for surface forcing and aerosol deposition over ocean
- Improved glacier model and sea-ice albedos
- Daily, ¼°- ocean boundary conditions (SST, Sea Ice Concen.)

# **MERRA-2**: Input, Output

## Assimilated Observations




## Data Delivery

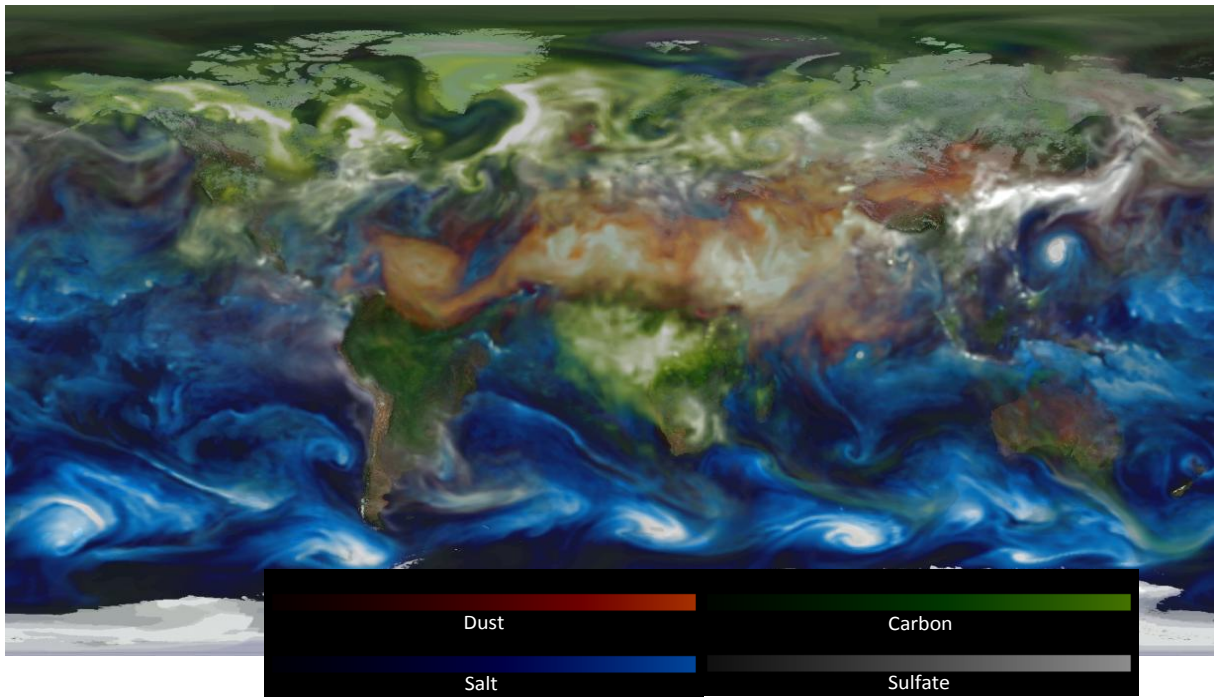
- 1980- present, run with 2- 3 week latency
- Hourly 2D fields (surface)
- 3- and 6-hourly 3D fields

| Daily Products | ~25 GB/ day | 9.1 TB/ year |
|---|---|---|
| Monthly Products | ~34 GB/ day | 408 GB/ year |

# MERRA-2: Coupled components

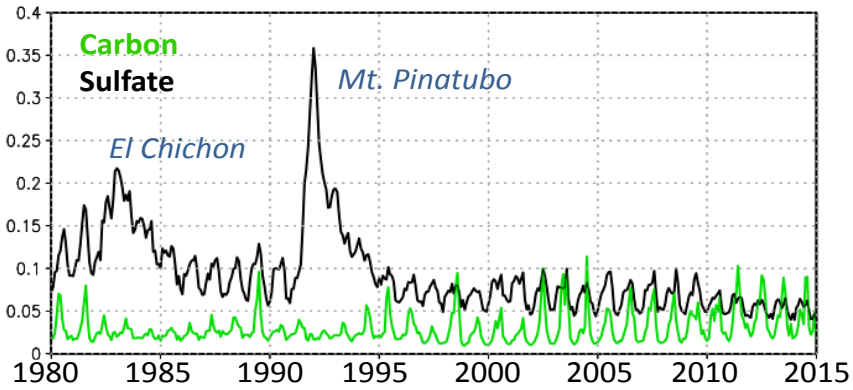
## Aerosol Assimilation

MERRA-2 Aerosol Analysis 10 July 2013 1200UTC

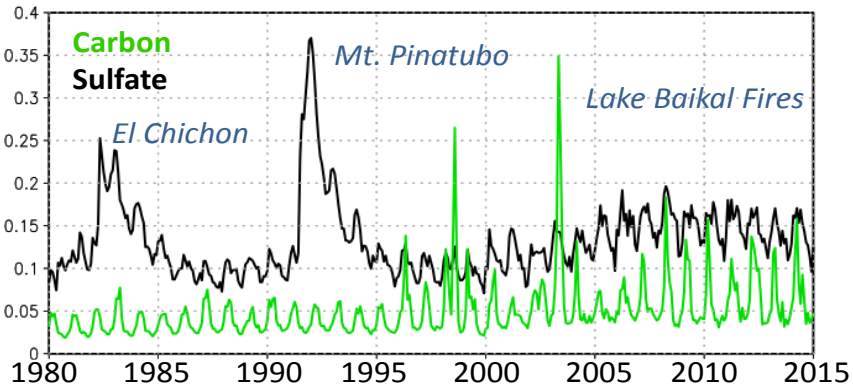



- **Black and organic carbon**, **dust**, **sea salt**, **sulfates**
- GOCART – mixing, chemistry and deposition
- Actively assimilated AOD from AVHRR, MODIS, MISR, AERONET
- Aerosols radiatively coupled with atmospheric model dynamics

**North America/Adjacent Atlantic AOD**




**East Asia/Adjacent Pacific AOD**



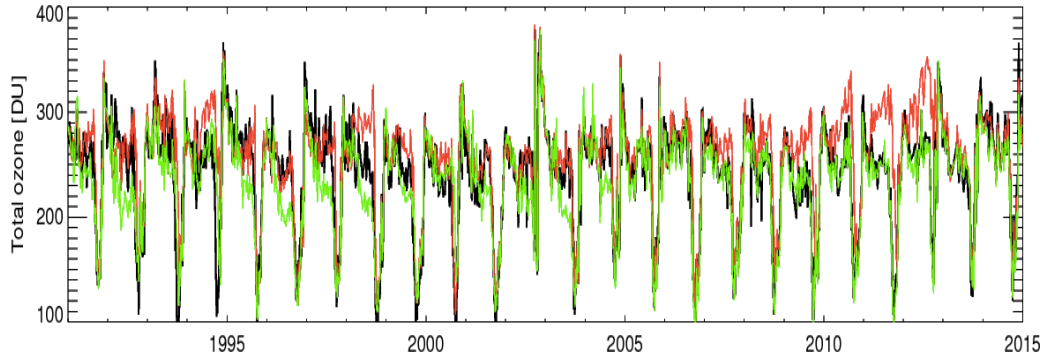
# MERRA-2: Coupled components

## Ozone Assimilation

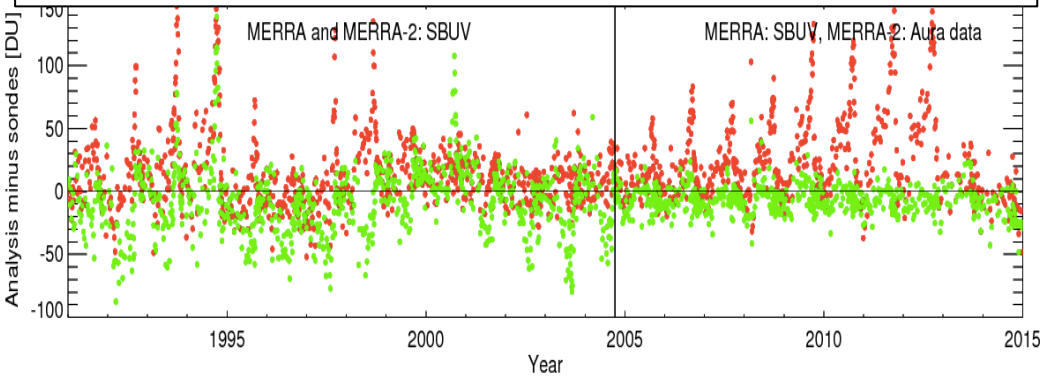
| Partial/total column | SBUV | 1980-2004 |
|---|---|---|
| Total column | OMI | 2004- … |
| Profiles | MLS | 2004- … |

MERRA-2 better agrees with sonde data 2005 onwards when EOS Aura MLS and OMI observations are assimilated

South Pole Total Column Ozone




**Ozone sondes** **MERRA** **MERRA-2**




| | 1991-2004 | 2005-2014 |
|---|---|---|
| **Sondes-Analysis difference** | **14.03 DU**<br>**-6.72 DU** | **26.56 DU**<br>**-6.77** |
| **Std. Dev of the sonde-analysis differences** | **30.19 DU**<br>**28.23 DU** | **36.00**<br>**11.10** |

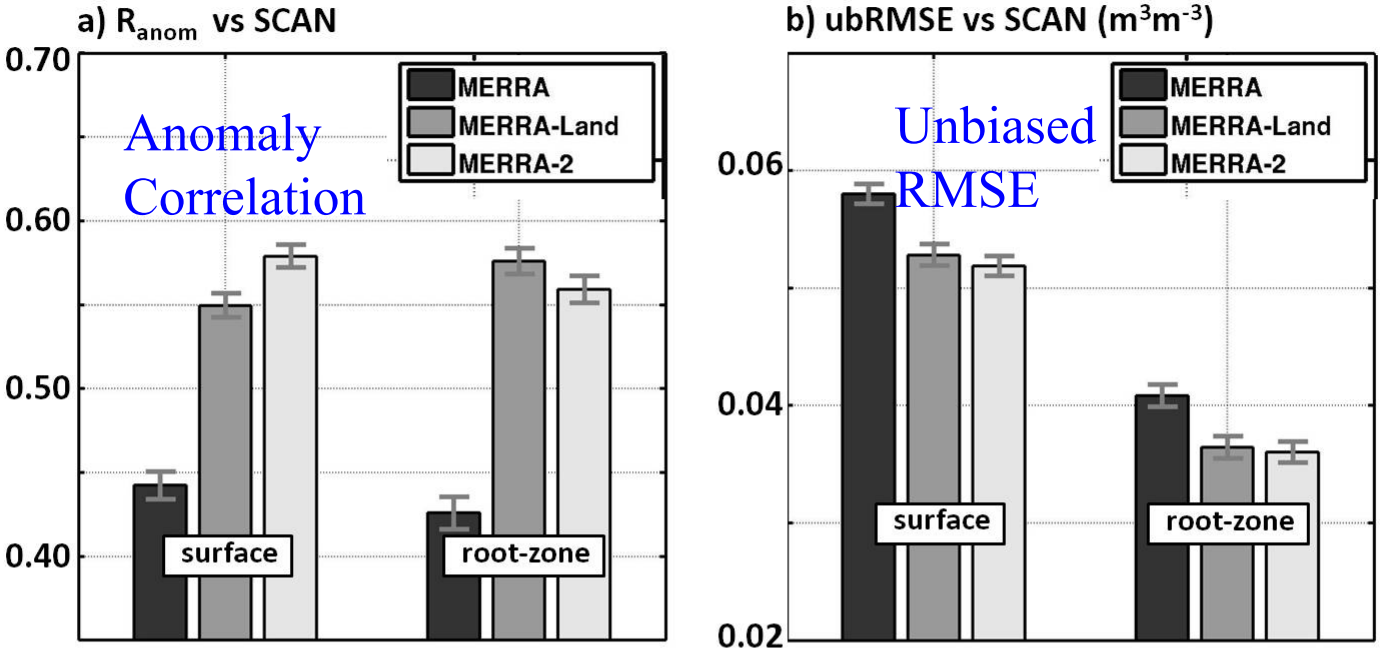
# MERRA-2: "loosely coupled"

**Precipitation Correction**

- to match gauge and/or satellite obs- it is *incident* at surface
- improves land hydrology and positively feeds back to atmospheric fields

Comparison w.r.t. SCAN **in-situ observations** (in US, 2002-2014)

**Soil Moisture (near-surface & root-zone)**




**MERRA-Land**:

- land only replay of MERRA
- included precip corrections

# **IESA:** Full Coupling

**Integrated Earth System Analysis** of

currently uncoupled assimilation systems (driven by MERRA-2):

1. Chemistry (CO, $CO_2$), Carbon cycle
2. Land (surface fields), soil and snow states
3. Ocean (physical) state

✧ Ocean bio-geo-chemistry (relies on items 1 and 3)

- More on this.. if time permits

# **IESA**: Chemistry ($CO$, $CO_2$, …)

**Plan:** fully coupled Carbon DA & Atmospheric DAS

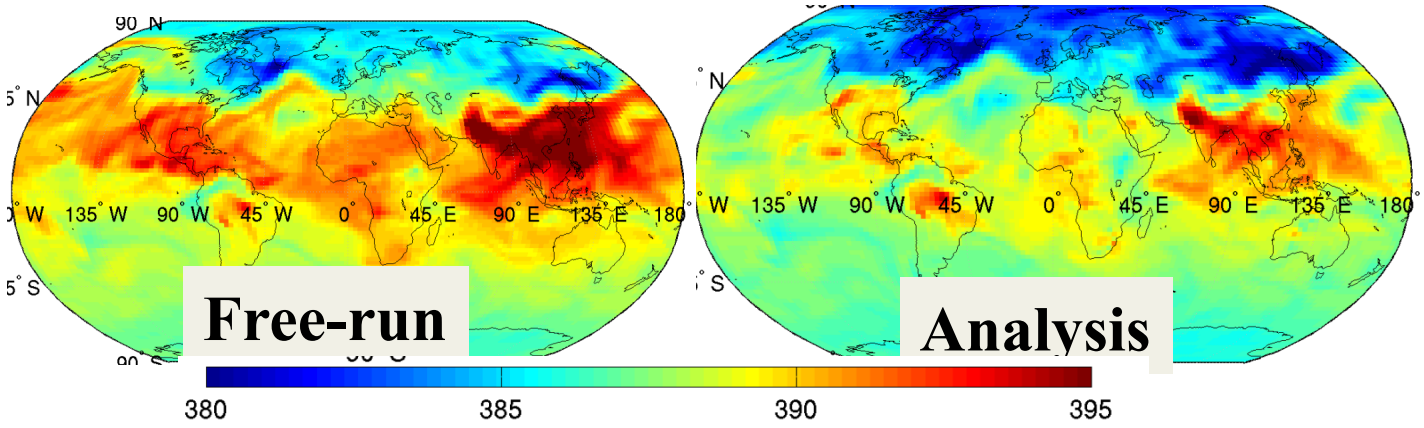
**Priorities**:

- Assimilate **column-averaged** $CO_2$ **retrievals** from GOSAT, OCO-2
- **Direct radiance assimilation** of OCO-2 observations

**Issues**:

- **Retrieval**: latency (24- 48 hrs) and biases; but regional data
- **Underestimation** of the **summer drawdown** by **boreal forests**- well known deficiency of land carbon models.

$XCO_2$ (ppmv) Aug 4, 2010- 12 UTC




Assimilation of GOSAT $CO_2$ reduces bias over N Hem

# IESA: Land Surface

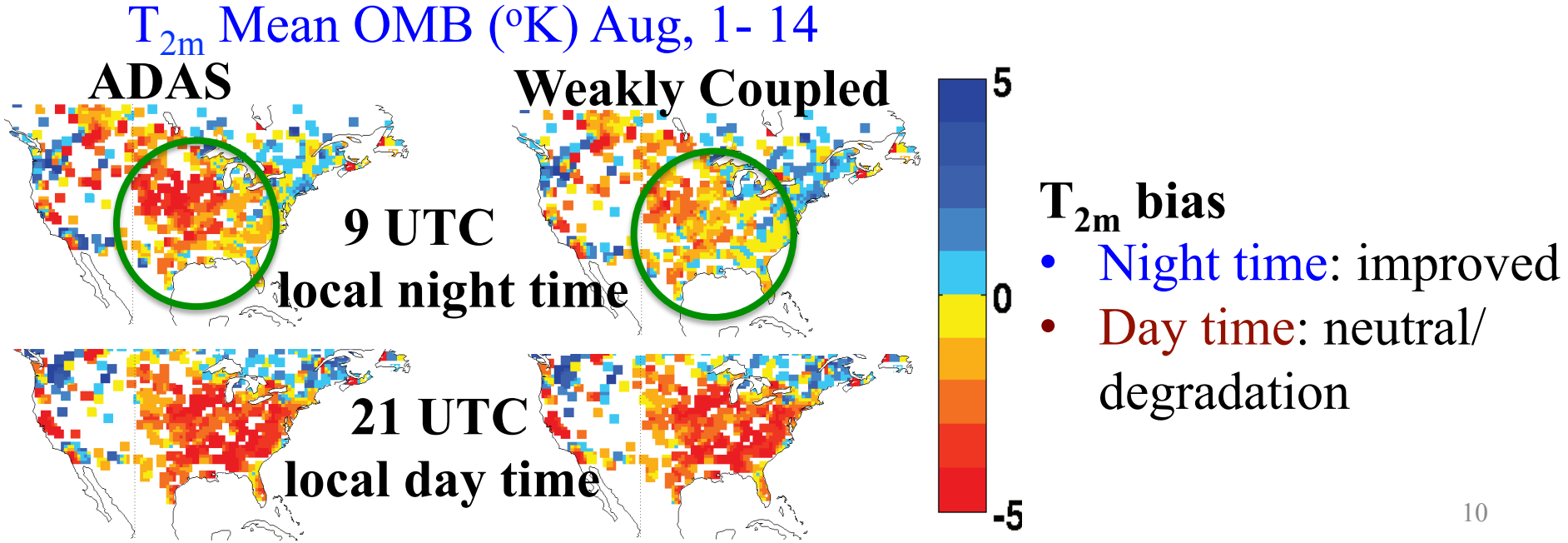
**Plan:** weakly coupled Land DA & Atmospheric DAS

**Priorities**:

- Near-surface soil moisture and snow cover fraction

**Issues**:

- Calibration and validation of heterogeneous surface with sparse obs
- Reconcile differences between model and observed variables

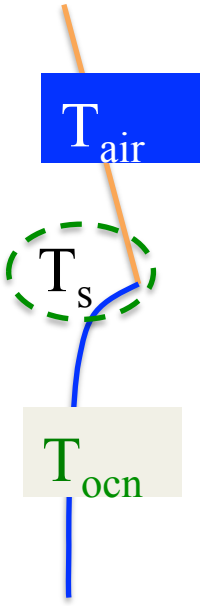


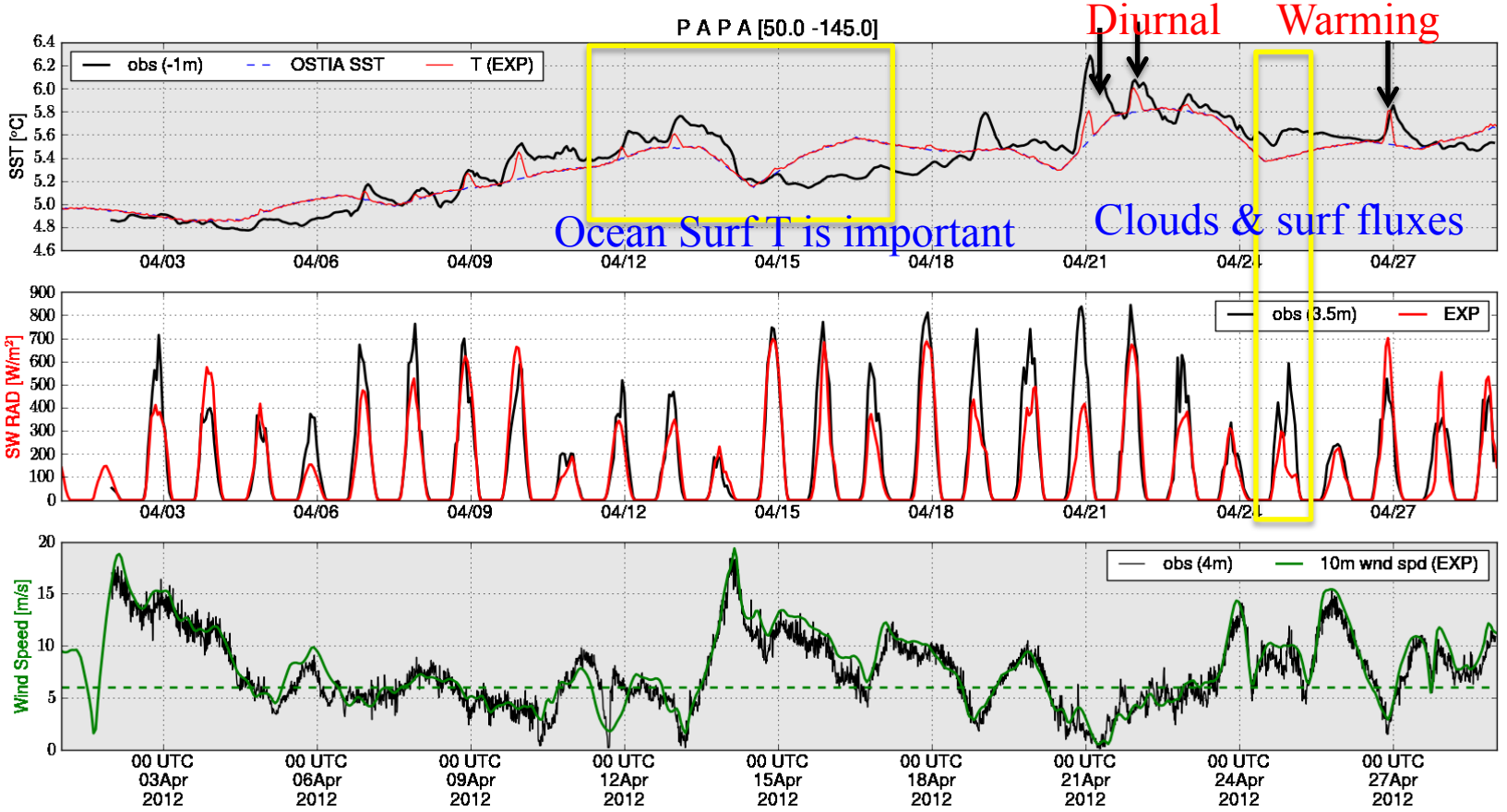
# IESA: Ocean

**Plan:** weakly coupled Ocean DA & Atmospheric DAS

- **Ocean surface T** = Ocean T (z=1) + Ocean Ana Increment

✓ Skin SST ($T_s$) = **Ocean surface T** + Diurnal warming – Cool skin + Atmos Ana Increment (direct radiance assimilation)

# Closing Remarks

- Ongoing work toward IESA
  - Chemistry
  - Land
  - Ocean
  - Ocean Bio-Geo-Chem

As *predictions improve*- across interfaces, analyses (sub-) components are modularly integrated (**ESMF**) into the GMAO systems:

- Weather forecasts
- S2S,
- Reanalysis (MERRA-3, …)

# BACKUP SLIDES

## **MERRA-2-Ocean**
(coupled AO-GCM replayed to MERRA-2 atmospheric analysis)

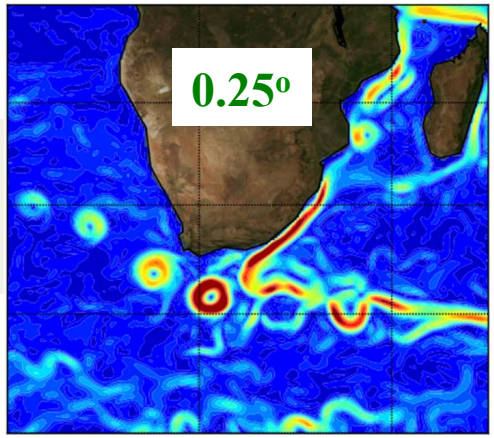
# **MERRA-2-Ocean**: Plan

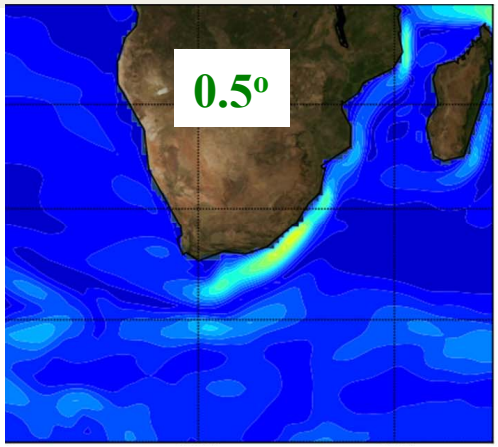
**AO-GCM configuration**

| | MERRA-2-Ocean | MERRA-Ocean |
|---|---|---|
| Atmosphere | MERRA-2 replay | MERRA replay |
| Ocean | MOM5 (*or 6?*) | MOM4-p1 |
| Ocean res | 0.25º tripolar; L50 | 0.5º tripolar; L40 |
| Sea-Ice | LANL CICE 4.1 (*or 5.1.2?*) | LANL CICE 4.1 |
| Run-off | Ice-sheets + Rivers | Rivers |

Ocean Surface Currents

**Eddy Permitting**



# **MERRA-2-Ocean**: Plan

**Assimilation of observations**

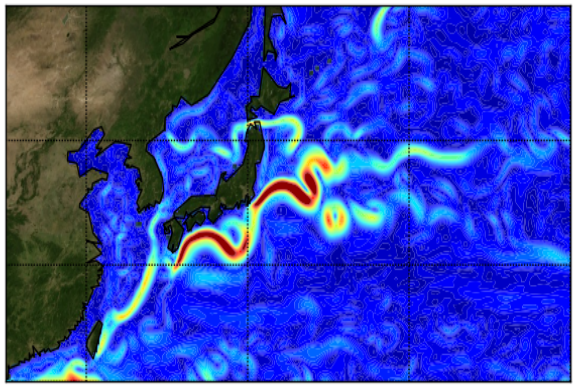
| | MERRA-2-Ocean | MERRA-Ocean |
|---|---|---|
| SST | OSTIA (*or Reynolds? or L2*) | Reynolds |
| Sea-Ice Concentration | NSIDC (*or Reynolds/SAF?*) | NSIDC |
| Sea Level Anomaly (*or Abs. Dyn. Topo.?*) | AVISO | AVISO |
| Sea Surface Salinity | *Pre-processed Aquarius?* | -None- |

In-situ

T&S (CTD, TAO, PIRATA, RAMA, ARGO; XBT-T)

# MERRA-2-Ocean: Issues

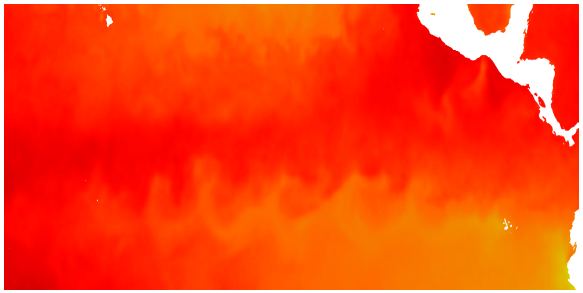
- Effectively **constrain meso-scale** features



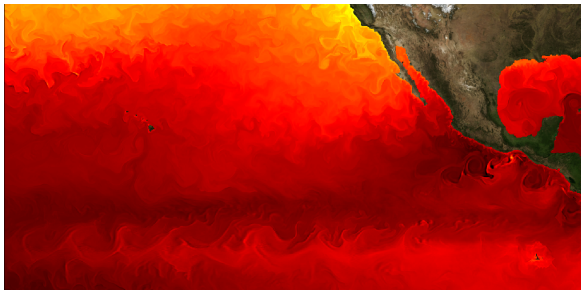
**Need to assimilate along track altimeter SSH (ADT)**

- **Gridded SST** (Optimal-interpolation products)

**0.05º OSTIA SST (1 Jan, 2014)**



**0.1º AXIOM-1 SST (1 Jan, 2014)**

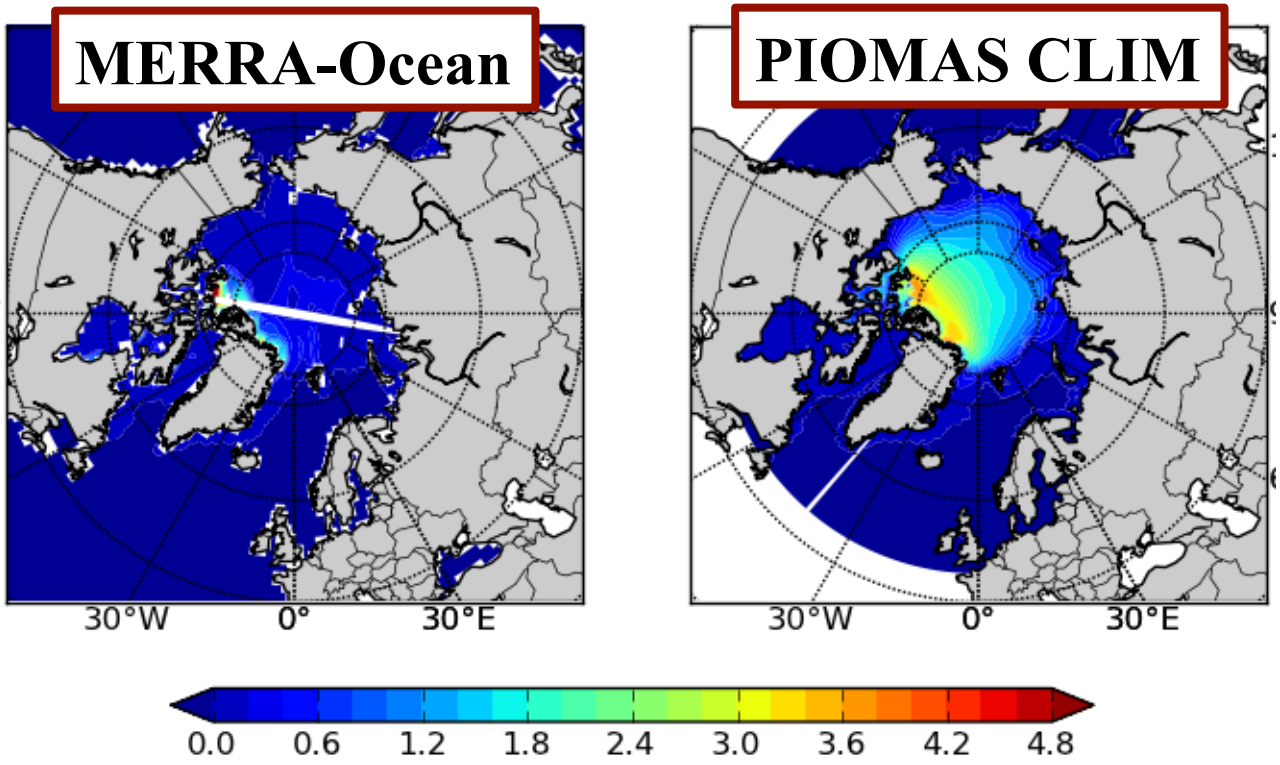


**Need to assimilate along track SST**

# **MERRA-2-Ocean**: Issues

- Sea Ice Concentration: assimilated (NSIDC, NASA Team-2 product)
- Sea Ice Thickness distribution: **un**constrained

**Sea Ice Thickness (m)**
**(Aug, 2015 Monthly Mean)**




Thickness significantly differs from climatology (PIOMAS):

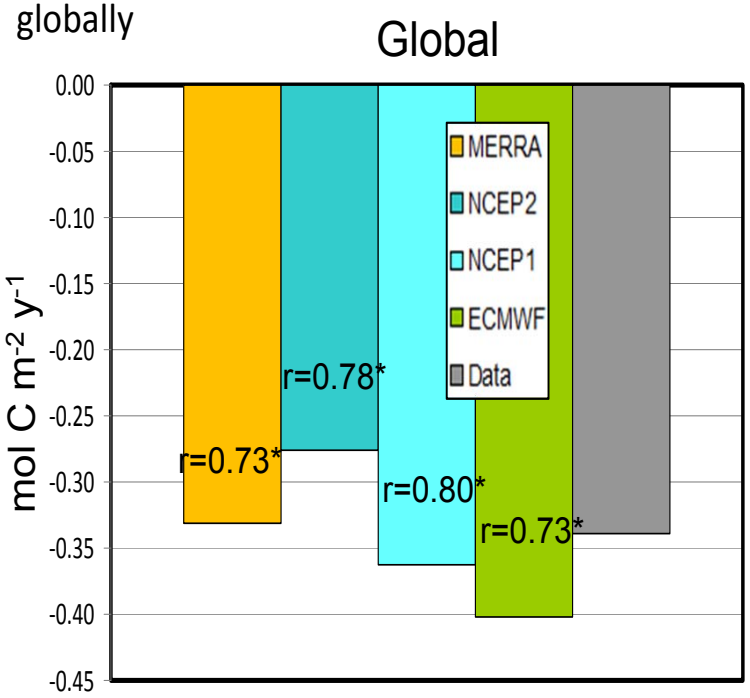
- *Assimilate CRYOSAT-2 freeboard?*
- *Calibrate CICE parameters?*

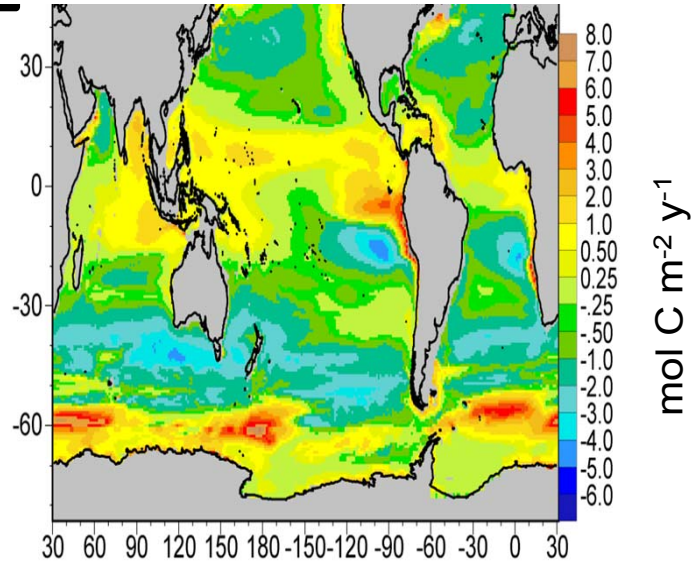

# EXTRA

# **IESA**: Ocean bio-geo-chemistry

**Existing Product:**

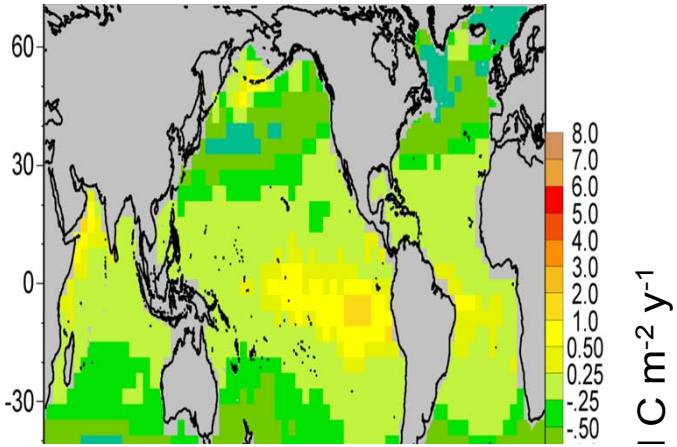
- Ocean $pCO_2$ and $CO_2$ fluxes from the NOBM-Poseidon
- Publicly available at carbon.nasa.gov for 2003-2012
- Current $pCO_2$ and $CO_2$ fluxes show agreement with in situ data
- Different reanalysis forcing data produce flux estimates within 20% globally




Ship based estimate

Of $CO_{2\ fluxes}$ (Takahashi et al., 2006)




**Development:**

- $pCO_2$ and $CO_2$ fluxes from the NOBM using Modular Ocean Model (both offline using Carbon Tracker data and online using GEOS-5)